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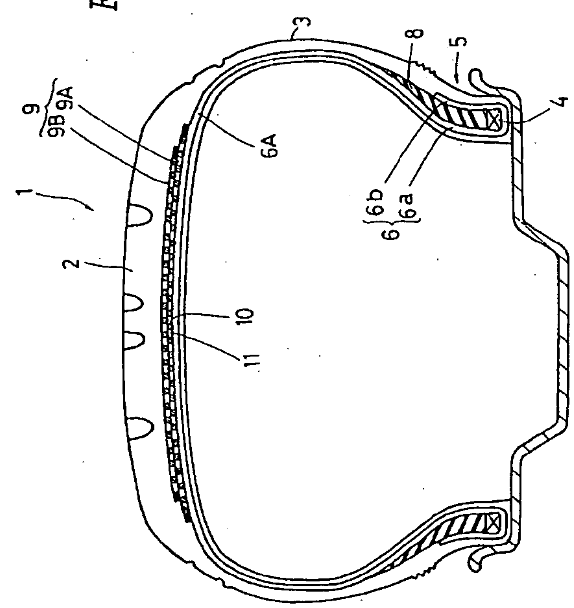
(54) Pneumatic tyre.

(57) A pneumatic tyre comprising a carcass (6) extending between bead regions (5) and a belt (9) disposed radially outside the carcass in a tread portion (2), said belt being made of cords (10) embedded in topping rubber (11) at an angle (theta) with respect to the tyre equator, characterised in that each said belt cord (10) comprising four steel monofilaments having the same diameters (d), said diameter (d) being from 0.2 to 0.35 mm, said four steel monofilaments including one or two waved steel monofilaments (12A) and unwaved steel monofilaments (12B), and said four steel monofilaments being compactly twisted together so as to make alternate contact portions and non-contacting portions between each said waved steel monofilament (12A) and the adjacent steel monofilaments.

Fig.1



EP 0 543 640 A1

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The present invention relates to a belted pneumatic tyre, in which the belt durability, steering stability and ride comfort are improved.

In general, radial tyres are provided with tread reinforcing belts. For such belts, a compact cord having a 1X3 structure has been widely used.

Such a 1X3 compact cord is composed of three steel monofilaments which are twisted together compactly. That is, no gap is formed between the adjacent filaments, as shown in Fig.6. Therefore, a closed space (H) is formed at the centre of the cord (A), and topping rubber (B) can not penetrate into this central space (H). As a result, the central part of the surface of the monofilament (F) is not covered by the topping rubber (B). The uncovered part is easily corroded by any water which penetrates the tyre tread portion from a damaged part, and the corrosion is liable to spread quickly through the space (H), which greatly reduces tyre durability.

In order to avoid such exposure of the steel monofilament surface, a loose cord has been proposed, wherein, as shown in Fig.7, straight steel monofilaments (F) are loosely twisted together. Therefore, penetration of topping rubber can be improved and,the surfaces of the filaments can be better covered by the topping rubber because, when the cord tension is small, the gaps (G) between the filaments are sufficiently large for the topping rubber to easily penetrate the cord.

However, because of the very large elongation of such a loose cord under a small load, when loose cords are assembled in a raw tyre as a belt and the tyre structure is pressurised in the vulcanising process, the belt tends to elongate or deform unevenly, which deteriorates tyre uniformity and also decreases belt rigidity. As a result, steering stability, rolling resistance, tyre life and the like are greatly decreased.

Further, if any tension is applied to the loose cord during rubberising of the cord, the gaps between the filaments becomes narrow or closed, which causes the same old problem of bad rubber penetration.

The present inventors discovered that the problems of the rubber penetration can be solved by waving one or two of the three steel filaments in a 1X3 structure cord.

In this improved structure, however, the three steel filaments form a triangular arrangement which is stable, and thereby the cord has a relatively high bending rigidity. As a result, ride comfort is somewhat deteriorated.

It is therefore, an object of the present invention to provide a pneumatic tyre having a belt in which, in order to solve the above-mentioned problems, the penetration of rubber into belt cords is improved, and the cord elongation under a small load is decreased, and further the bending rigidity of the belt cords is decreased.

According to one aspect of the present invention, a pneumatic tyre comprises a carcass extending between bead regions, and a belt disposed radially outside the carcass in a tread portion, said belt being made of cords embedded in topping rubber at an angle (theta) with respect to the tyre equator, characterised in that each said belt cord comprises four steel monofilaments having the same diameters (d), said diameter (d) is 0.2 to 0.35 mm, said four steel monofilaments including one or two waved steel monofilaments and unwaved steel monofilaments, said four steel monofilaments being compactly twisted together so as to make alternate contact portions and non-contacting portions between each said waved steel monofilament and the adjacent steel monofilaments.

As the steel monofilaments are compactly twisted together, the cord elongation under a small load is smaller than a loose cord. However, as the twisted monofilaments include one or two waved monofilaments, the topping rubber easily penetrates the cord through the resultant gaps at the non-contacting portions.

Further, so as not to form a rigid triangular arrangement, four filaments are used in one cord. Further, all the filaments, one or two of which are waved, have the same diameter. Therefore, the distance balance between the four filaments is disturbed, and the cord can be bent easier than the 1X3 cord.

Embodiments of the present invention will now be described in detail in conjunction with the accompanying drawings, in which:

Fig.1 is a cross sectional view of a tyre according to the present invention;

Fig.2 is a perspective view of a belt cord;

Fig.3 is a cross sectional view of an opened part of the belt cord;

Fig.4 is a plan view of a waved monofilament used in the belt cord;

Fig.5 is a plan view of an unwaved monofilament used in the belt cord; and

Figs. 6 and 7 are cross sectional views of belt cords explaining the prior art.

In Fig.1, a pneumatic tyre 1 has a tread portion 2, a pair of bead regions 5, and a pair of sidewalls 3 extending between the tread edges and the bead regions 5.

The tyre 1 comprises a bead core 4 disposed in each bead region 5, a carcass 6 extending between the bead regions 5 and turned up around the bead cores 4 to form two carcass turned up portions 6b and one main portion 6a, and at least one tread reinforcing belt 9 (in this embodiment two belts 9A and 9B) disposed radially outside the carcass 6 in the tread portion 2.

The carcass 6 comprises at least one ply 6A of cords laid at 75 to 90 degrees with respect to the tyre equa-

tor.

Between the carcass main portion 6a and each of the turned up portions 6b, a bead apex 8 made of hard rubber is disposed. The bead apexes extend taperingly radially outwardly from the bead cores 4 to reinforce the bead regions 5 and lower sidewalls 3 and thereby increase the lateral stiffness of the tyre.

The carcass 6 in this embodiment is composed of one ply 6A of nylon fibre cords.

For the carcass, organic fibre cords, e.g. polyester, rayon, aromatic polyamide or the like, are preferably used. However, steel cords can be used.

In this embodiment, the radially inner belt 9A disposed on the carcass 6 is wider than the radially outer ply 9B disposed on the inner belt ply 9A. The belt 9 as a whole has enough width to reinforce the whole width of the tread portion 2.

Each of the belts 9A and 9B is made of parallel cords 10 embedded in topping rubber 11 and laid at an angle (theta) from 12 to 25 degrees with respect to the tyre equator so that the cords in the inner belt 9A cross the cords in the outer belt 9B.

In the present invention, the belt cord 10 is composed of only four steel monofilaments 12 which are twisted together as shown in Fig.2, wherein one or two of the four steel monofilaments are waved, and the remaining three or two steel monofilaments are not waved.

In the example shown in Fig.2, only one filament is waved. However, the belt cord 10 more is preferably composed of two waved monofilaments 12A and two unwaved monofilaments 12B.

Fig.4 and Fig.5 show a single waved monofilament 12A and a single unwaved monofilament 12B, respectively, before they are twisted into a cord. As shown in Fig.4, the waved monofilament 12A is waved in advance. As shown in Fig.5, the unwaved monofilament 12B is straight.

The four monofilaments 12A and 12B in one cord have the same diameter (d).

Accordingly, when they are twisted as shown in Fig.2, the belt cord 10 is provided with non-contacting portions P between the waved monofilament 12A and the adjacent monofilaments all along the length of the cord. Thus, openings or gaps T are formed at each non-contacting portion P as shown in Fig.3, through which the topping rubber penetrates the central space of the cord.

The waved monofilament 12A can be waved two-dimensionally by bending a straight monofilament in a flat plane at small pitches.

Alternatively, the waved monofilament 12A can be waved three-dimensionally by coiling a straight monofilament at a small diameter and small pitches.

The wave pitches are preferably 0.31 to 0.70 times the cord twist pitches.

The wave height (from peak to peak) is preferably 1.5 to 2.5 times the diameter (d) of the filaments 12A and 12B.

In the present invention, the waved monofilament 12A and the unwaved monofilament 12B are twisted compactly so that the adjacent filaments generally contact each other. Accordingly, the elongation thereof becomes smaller than that of a loose cord.

The above mentioned gaps T at the non-contact portions P are not more than 0.6 times the diameter (d).

In order to maximise the steering stability and tyre uniformity, it is preferable that the elongation of the belt cord 10 under 5 kgf load is less than 0.3%.

To achieve this by providing strength in the belt, the above-mentioned diameter (d) is set in the range from 0.20 to 0.35 mm, more preferably 0.25 to 0.28 mm.

If the diameter (d) is less than 0.2 mm, the cord is not provided with sufficient strength.

On the other hand, if the diameter (d) is more than 0.35 mm, the cord diameter and thereby the belt thickness increase and as a result the tyre weight undesirably increase.

On the other hand, the rubber compound used as the topping rubber 11 has a complex elastic modulus E* of 45 to 150 kgf/cm^2.

Here, the complex elastic modulus E* is measured under the following conditions: 10% initial strain, 10 Hz sine wave with 2% amplitude, and temperature of 70 degrees C, using a test piece (4mm width, 30mm length, and 2mm thickness), by a visco-elasticity spectrometer of IWAMOTO SEISAKUSYO manufacture.

If the complex elastic modulus E* is less than 45 kgf/cm^2, the belt rigidity becomes insufficient for good steering stability, and the cut resistance of the belt cords during sharp cornering is decreased.

If the complex elastic modulus E* is more than 150 kgf/cm^2, it becomes difficult for the topping rubber to penetrate the cord.

Further, the buckling strength coefficient K of each of the belts is more than 80 and less than 165.

Here, the buckling strength coefficient K is defined by the cord count M per 5cm width divided by sin (theta). The angle (theta) is the belt cord angle with respect to the tyre equator. (12 deg < theta < 25 deg).

If the buckling strength coefficient K is not more than 80, the cut resistance of the belt cord during sharp cornering and the steering stability are deteriorated.

If the buckling strength coefficient K is not less than 165, ride comfort is deteriorated, and the tyre weight increases.

Test tyres of size 195/70R14 having the structure shown in Fig.1 and specifications given in Table 1 were prepared and tested. The test results are also given in Table 1.

(1) Penetration of the topping rubber into the belt cord was measured as follows:

Four belt cords were taken out of the test tyre. For each of the four belt cords, one of the four steel monofilaments therein was separated from the three others carefully so as not to remove the penetrated rubber using a sharp edged tool, and then the inner surfaces of the remaining three steel monofilaments were observed to determine whether the inner surfaces were exposed or not. Such determination was made for every cord twisting pitch.

If the surface was exposed, it was determined that the topping rubber had not penetrated that part (pitch).

For each of the belt cords, the percentage of the penetrated parts (twist pitches) was calculated from the following equation:

$$\frac{\text{the number of the penetrated pitches} \times 100}{\text{the whole number of the pitches included in the cord}}$$

From the calculated four values in each test tyre, the mean value thereof was obtained as the rubber penetration index for the tyre.

(2) The resistance to corrosion of the steel belt cords of each of the test tyres was measured as follows:

Eight holes reaching to the radially outer belt were provided in the inside of the test tyre, and salt water was put into the tyre cavity, and then the tyre was run for 30,000 km at a speed of 60 km/h under a 120 % of the standard tyre load (the maximum load specified in JIS).

After the 30,000 km running, the area of the corroded part of the radially outer belt was measured as the resistance to corrosion, and indicated by an index based on that Reference tyre 2 is 100. Therefore, the smaller the index, the better the resistance.

(3) The cut resistance was evaluated by the cut caused by sharp cornering of the test car.

In Table, the cut resistance is indicated by an index based on that Reference tyre 2 is 100. The large the index, the better the resistance.

(4) The steering stability and ride comfort were evaluated by a test driver into five ranks, wherein the rank three is standard. The larger the value, the better the performance.

TABLE 1

Tyre	Ref.1	Ref.2	Ref.3	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5	Ex.6
No. of steel monofilaments	5	4	4	4	4	4	4	4	4
Filament dia. (mm)	0.23	0.25	0.25	0.25	0.28	0.25	0.25	0.25	0.25
Cord count (ends/5cm)	37	37	37	37	30	37	50	37	37
Cord twist	compact	compact	loose	compact	compact	compact	compact	compact	compact
No. of waved monofilament	0	0	0	1	1	2	1	1	1
Cord elongation @ 5kgf load (%)	0.12	0.125	0.43	0.172	0.158	0.190	0.172	0.172	0.32
Topping rubber complex elastic modulus (kgf/cm^2)	68	68	68	68	68	68	68	160	68
Buckling strength coefficient	120	120	120	120	97	120	171	120	120
Rubber penetration (index)	0	5	90	95	95	98	95	60	98
Belt cord weight (g/tyre)	750	700	710	700	720	700	850	700	700
Corrosion resistance	120	100	25	20	20	18	20	40	18
Cut resistance	125	100	105	100	110	100	145	110	107
Steering stability	3.2	3.1	2.8	3.2	3.1	3.0	2.9	3.1	2.9
Ride comfort	2.8	2.9	3.2	3.2	2.9	3.1	2.7	3.0	3.0

Claims

1. A pneumatic tyre comprising a carcass (6) extending between bead regions (5) and a belt (9) disposed radially outside the carcass in a tread portion (2), said belt being made of cords (10) embedded in topping rubber (11) at an angle (theta) with respect to the tyre equator, characterised in that each said belt cord (10) comprising four steel monofilaments having the same diameters (d), said diameter (d) being from 0.2 to 0.35 mm, said four steel monofilaments including one or two waved steel monofilaments (12A) and unwaved steel monofilaments (12B), and said four steel monofilaments being compactly twisted together so as to make alternate contact portions and non-contacting portions between each said waved steel monofilament (12A) and the adjacent steel monofilaments.

2. A pneumatic tyre according to claim 1, characterised in that a gap (T) between said four steel monofilaments at each said non-contacting portion is not more than 0.6 times said diameter (d).

3. A pneumatic tyre according to claim 1 or 2, characterised in that the elongation of the belt cord under 5kgf load is not more than 0.3%.

4. A pneumatic tyre according to claim 1, 2 or 3, characterised in that the topping rubber for the belt cords has a complex elastic modulus of 45 to 150 kgf/cm^2.

5. A pneumatic tyre according to claim 1, 2, 3 or 4 characterised in that the buckling strength coefficient K of said belt is more than 80 and less than 165, said buckling strength coefficient K being defined as the belt cord count per 5cm width of the belt divided by sin (theta) above the angle (theta) is the belt cord angle to the tyre equator.

6. A pneumatic tyre according to any of claims 1 to 5, characterised in that each said belt cord is composed of two waved steel monofilaments (12A) and two unwaved steel monofilaments (12B).

Fig. 1

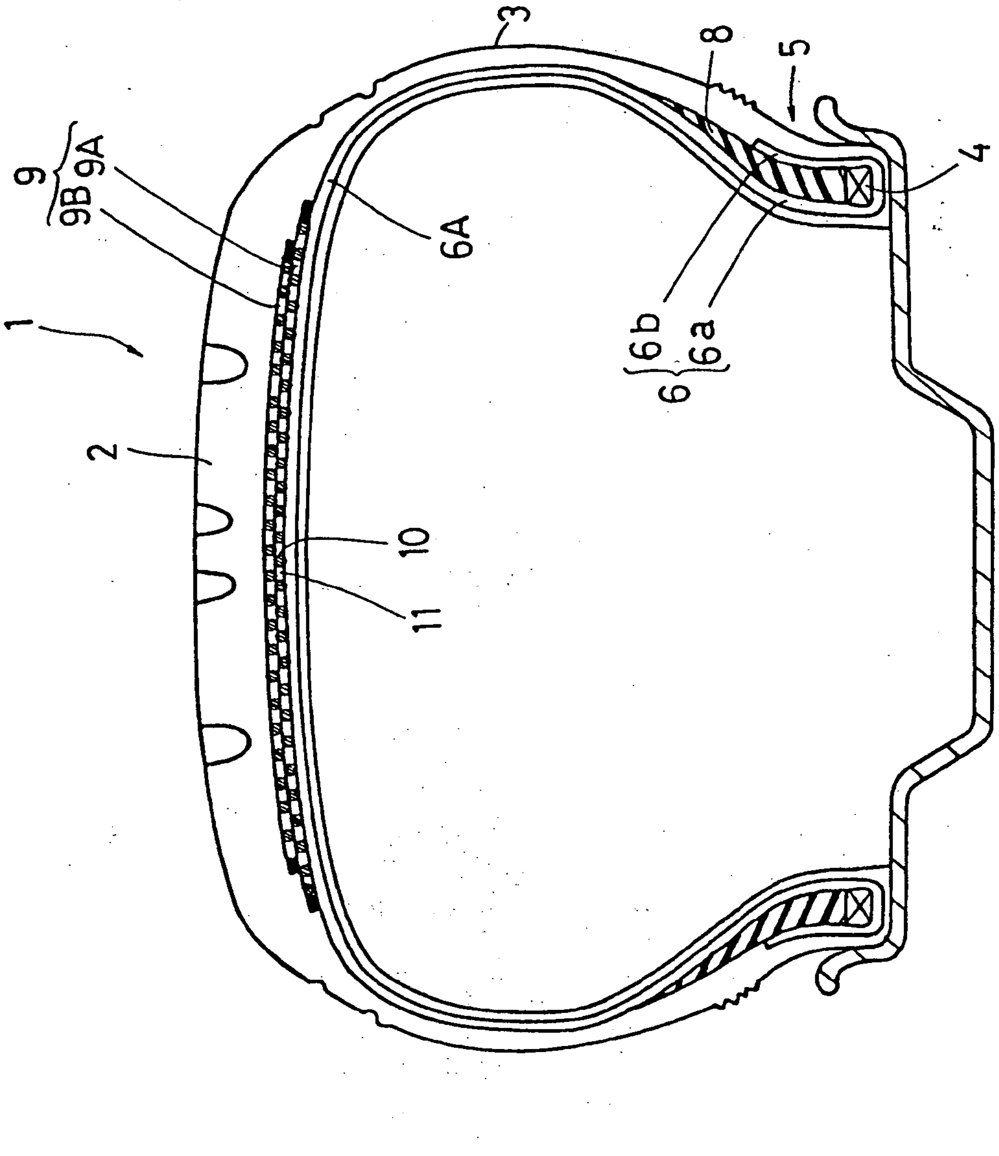


Fig.2

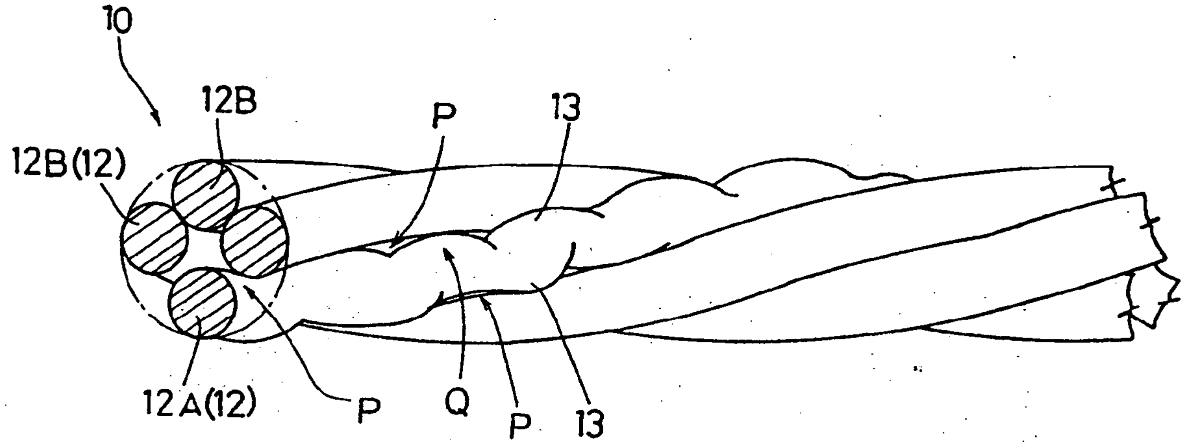


Fig.3

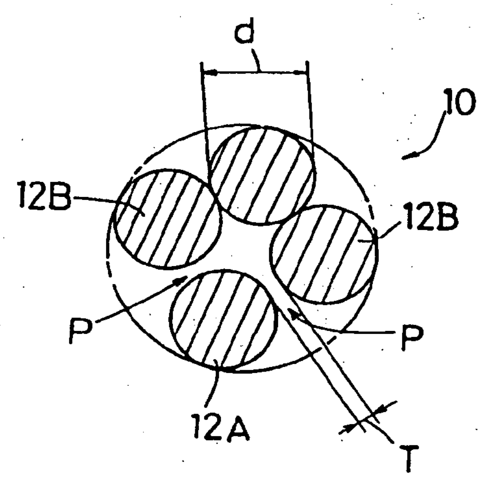


Fig.4

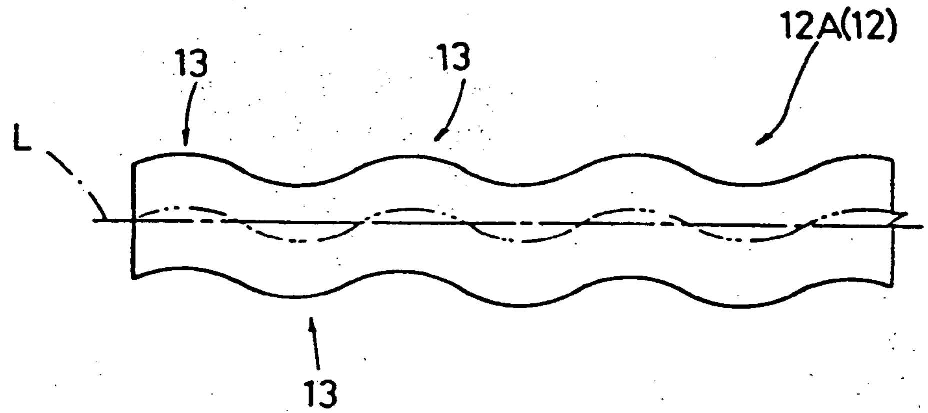


Fig.5

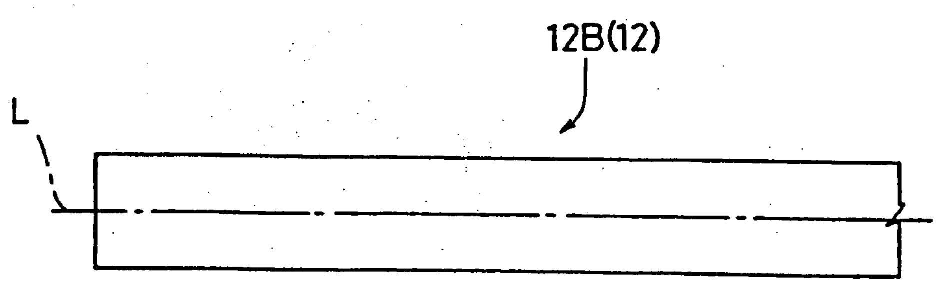


Fig. 6

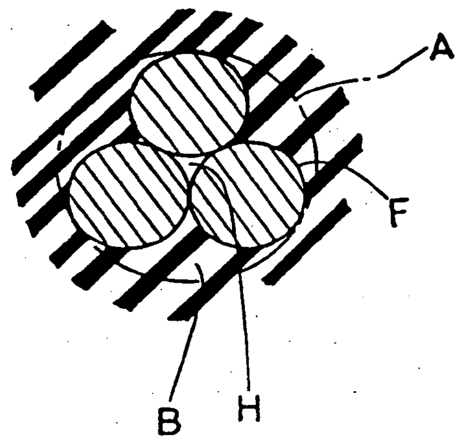
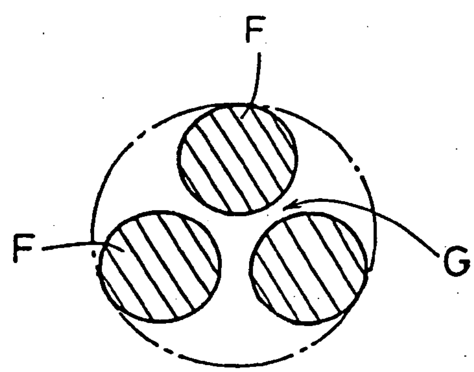


Fig. 7



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EUROPEAN SEARCH REPORT

Application Number

EP 92 31 0527

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
E	EP-A-0 515 178 (SUMITOMO RUBBER INDUSTRIES LTD.) * claims; figures *	1-6	B60C9/00 D07B1/06
P,X	EP-A-0 462 716 (TOKUSEN KOGYO CO. LTD.) * page 3, column 4, line 17 - page 5, column 7, line 3; claims; figures 4B,16 *	1-6	
Y	EP-A-0 433 962 (TOKUSEN KOGYO CO. LTD.) * page 2 - page 4; claims; figures; table 2 *	1-3	
Y	US-A-4 738 096 (K.HATAKEYAMA ET AL.) * claims; figures 2,3; table 1 *	1-3	
A	EP-A-0 146 046 (MICHELIN &CIE) * claims; figures *	1	
A	WO-A-9 104 370 (BEKAERT S.A.) * claims; figures *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B60C
D07B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	08 FEBRUARY 1993	BARADAT J.L.

CATEGORY OF CITED DOCUMENTS

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